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CEMENT CLINKER FORMATION IN CONCENTRATED CARBON DIOXIDE ATMOSPHERES

Mineralogical and reactivity insights

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Akademisk avhandling

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Abstract
The research presented in this thesis investigated cement clinker production, and involved replicating the conditions of electrified kilns using plasma heating and emerging technologies such as oxy-fuel combustion and calcium looping. These technologies aim to address key challenges in sustainable cement manufacturing by enabling carbon capture and improving process efficiency, and involve the use of high-CO_2 atmospheres. Reliable experimental and analytical methods, including high-temperature X-ray diffraction with controlled atmospheres, were developed in order to study the calcination behaviour, burnability, and phase evolution of raw meals. The key findings were that high-CO_2 conditions shift the calcination temperature, decomposition, and modification of intermediate phases, and enhance the reactivity of key phases such as C_2S. Accelerated C_2S formation and spurrite decomposition play a critical role in improving burnability and C_3S formation, reducing reliance on free lime as an intermediate. Optimised raw meals with improved fineness and tailored chemical compositions demonstrated superior burnability and enhanced clinker reactivity as compared to conventional industrial samples. These results indicate the potential for improving raw meal formulations in order to meet the demands of conventional and emerging processes. However, challenges persist in managing sulphur volatilisation, and alkali dynamics under high-CO_2 conditions. This study emphasises the importance of addressing process factors such as material flow, heat transfer, and kiln volatilisation for ensuring industrial scalability. The findings of the simulation of calcium looping conditions highlight that carbonation efficiency and clinker phase formation depend on factors beyond C_2S reactivity, including particle sintering and temperature dynamics. This work provides critical insights into the implications of high-CO_2 atmospheres for clinker production, offering valuable guidance for developing electrified and decarbonised cement processes. The research lays the foundation for producing durable cement in a sustainable way, with a view to reaching global climate goals by bridging the gap between laboratory-scale studies and industrial applications.

Keywords
Portland cement, clinker, phase evolution, in-situ XRD, carbonation, calcination, hydration, carbon capture

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